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Turbulence as a significant factor of modern economic processes: Theoretical aspects

The author has analyzed the notion of "turbulence", which is widely applied in the sphere of economic studies. The analysis gives reasons to state, that turbulence is a characteristic feature of economic dynamics processes. Application of the procedural approach in macroeconomics presupposes usage of such notions as turbulence and relative velocity of processes.

Turbulence shows itself in a relative velocity of specific processes, under which economic system can lose its stability. The author emphasizes that balance is a state of economic system under zero or minimal velocity of its elements. Turbulence as a mechanism of instability appears under not-null velocity of the system elements. In this sense turbulence is a characteristic of components of any process to acquire relative velocity. Analysis of economic processes let us conclude that the reason for turbulence is a display of relative velocity of the system's separate elements without sacrificing maximum velocity of cooperation circulation. Such approach gives reasons to apply the Lorentz transformation for mathematical description of turbulence of economic phenomena.

Keywords: *turbulence, economic system, economic processes, velocity of elements of the economic system, economic dynamics.*

Турбулентність як важливий чинник сучасних економічних процесів: теоретичні аспекти

У статті проаналізоване поняття «турбулентність», яке широко використовується в сфері економічних досліджень. Проведений аналіз дає підстави зазначити, що турбулентність – це властивість процесів економічної динаміки. Застосування процесуального підходу в макроекономіці передбачає використання понять турбулентність і відносні швидкості процесів.

Турбулентність проявляється у відносній швидкості перебігу конкретних процесів, в яких економічна система здатна втрачати стійкість. Автор наголошує, що рівновага – це стан економічної системи при нульовій чи мінімальній відносній швидкості її елементів.

Турбулентність як механізм нестійкості виникає при не нульовій відносній швидкості елементів системи. У цьому сенсі турбулентність – властивість складових елементів будь-якого процесу набувати відносну швидкість. Аналіз економічних процесів дозволяє зробити висновок, що причина турбулентності – прояв відносної швидкості окремих елементів системи при збереженні в ній максимальної швидкості поширення взаємодії. Такий підхід дає можливість застосувати перетворення Лоренца для математичного опису турбулентності економічних явищ.

Ключові слова: *турбулентність, економічна система, економічні процеси,швидкість руху елементів економічної системи, економічна динаміка.*

Cardinal changes, which are observed in global economy, will have long-standing macro-economic consequences for all countries. Instability of the world economic system, its dynamic nature and contradiction of managerial influences, on the one hand is a threat for a business system and can lead to various crisis phenomena, and on the other hand opens opportunities, pushes to a search of new sources for economic development and modernization of economic system. One of the characteristic features of economic systems is their turbulence, which is revealed in an irregular movement, which is characterized by a rapid change of market tendencies and strong tides of economic indices, stepwise variations of static states of the system, which initiate considerable differences in the rate of their pace and directionality[1].

In modern Ukraine the notion of "turbulence" is widely applied in the sphere of economic studies. But its usage is based not on an elaborated theoretical and methodological base, but only on intuitive comprehension. Turbulence is usually interpreted as an irregular movement, characterized by a rapid change of market tendencies and strong tides of economic indices [2]. Thus, let us designate how appropriate is to use the notion of "turbulence" while analyzing economic systems, what the turbulence of the economic system is, and how important the analysis of the economic systems is for studying turbulence.

The analysis of variability of economic environment is traditionally believed to be one of the most important tasks in economic studies. However, historically the economists paid main attention to exposure of regularities in static states of the economic system. D. Nort in his 1993 Nobel lecture stated that there is no theory of economic dynamics. In fact, traditional approaches do not allow explaining volatility of processes in the economic environment. In modern economic science it is interpreted as a stepwise change of static states. Such approach was characteristic for research in the 19th -20th century.

[1] Prokhorova O. V. Faktory ustoichivosti rehionalnoi ekonomicheskoi sistemy v usloviiakh turbulentnosti / O. V. Prokhorova // Molodoi uchenyi. – 2015. – №21.1. – Pp. 18-22.

[2] Dobrocheev O. Pravila Dobrocheeva. Russkii Khaos – eto tot zhe nemetskii poriadok, no tolko dlia ochen bolshoi strany / O. Dobrocheev [Electronic resource]. – Access mode: http://www.peremeny.ru/books/ osminog/1679

Theories of economic growth are mainly restricted to determination of the set of factors, which designate equal states of the economic system. The IS-LM model (investment – saving, liquidity preference – money supply), developed by John Hicks on the basis of J. M. Keynes' ideas, shows the direction of changes of static states under changes of interest rates and income. At the same time it presupposes balanced demand for money and its supply, as well as savings and investment. Economic multipliers are the tools for analysis of qualitative changes only of some indices. System-oriented analysis, widely used in economic sciences, is a study of the system's static states. The theory of economic mechanisms (L. Hurwicz, R. Myerson, E. Maskin) mainly deals with peculiarities of markets functioning, including under asymmetry of information and possibility to apply special institutions and procedures to ensure market stability. However, the theory does not directly touch on the problem of dynamics.

To characterize the state of economic system one traditionally uses balance correspondences "demand – supply", "revenues – expenses", "production – marketing", "savings – investment". At the same time main attention is focused on the factors aimed to achieve balance, and not factors of its unbalancing. Thus, dynamics of the economic system is in fact understudied. We suppose that economic dynamics can be defined as a totality of processes, which pass with different intensity, influence each other, coincide in direction or are differently directed. The process, in its turn, is a shift of states, which is characterized by certain velocity. Namely, the latter distinguishes a dynamic state from a static one[3].

The theory of economic dynamics first of all studies the processes which take place within an economic system; secondly, relative velocity of its elements, i.e. the difference between the rate of dynamics. In particular, a shift in correlation between the processes of agreement undertaking (formation of obligation of business units) and their execution in the course of mutual payments is a major factor of instability. Analyzing dynamics one mainly pays attention not to structural, but procedural parameters of the economic system and correspondingly procedural approach to its functioning[4].

The most complicated manifestation of economic dynamics is high volatility of processes, which depends on considerable differences in the pace and directionality. First of all instability is inherent to the processes of price formation, currency rates and exchange quotation. Their changes are represented in time by a complicated and often chaotic movement. But considerable instability is peculiar of other economic processes: formation of demand and supply at the market of factor of production, consumption and savings, investment, product marketing, calculation, generation of budget revenues and expenditures and so on.

In economic analytics and scientific papers instability is interpreted as tides of corresponding indices. But it can be represented as a complicated spiral movement or a whirl formation.

[3] Olsevych Yu. Ya. Sovremennyi krizis "meinstrima" v otsenkakh eho predstavitieliei (predvaritelnyi analiz). – M.: Institu ekonomiki RAN, 2013. –P. 12

[4] [4] Zhuravlova H.P., Manokhina N.V. Novyie pravila ihry v usloviiakh ekonomicheskoi turbulentnosti / H.P. Zhuravlova, N.V. Manokhina // Vestnik SHSEU. – 2013. – Issue №5 (49). – P. 27.

Ph. Cotler and J. A. Caslione define turbulence as a process of destruction in the form of hurricanes, tornados, cyclones or tsunamis. In all these cases stability and predictability disappear. In economy turbulence, as a rule, is so much unpredicted and prolonged, that causes decline or protracted crisis[5].

On the basis of V. Prihozhin's works on non-linear dynamics and B. Mandelbrot's theory of fractals (geometric figures, which are characterized by self-similarity and fractional dimensions)[6] were made a range of attempts to study economic processes by means of non-linear equations and find fractal structures and laws of similarity within market variables. In terms of the received data now the following definition is formed: economy is referred to the systems, which are non-integrated as J. Poincare stated. It means that in economic environment always appear new factors, which cannot be accounted at the initial stage of analysis and predicting calculations.

Manifestation of similarity laws and existence of fractal structures, i.e. instability, are possible only under the conditions of endurance of informational flows. Correspondingly, absence of fractal structures testifies instability of information flows in economy. As a result appear problems in modeling economic processes and their forecasting, irresistible for modern times. Difficulties in studying economic dynamics are also connected with understudied methods of analysis, which let make accents on volatility of processes in the economic system. One of the lines of development of such methods is studying turbulence, which requires examination of processes, which stipulates formation of systems and evolution of their specific elements.

From the methodological point of view a question of using such notions as "pace" and "velocity" in analyzing economic processes is quite urgent. On the contrary to velocity pace is a dimensionless index.

In natural sciences velocity is a major characteristic of turbulence. In physics it is studied as a relation of space dimension to time. In chemistry velocity of reaction is a quantity adjustment of material particles per unit time, i.e. it does not possess special characteristic. Thus, there is no universal notion of velocity, which indicates a possibility to apply its broad interpretation in economics, as a relation of paces of interrelated economic processes. This index is a quantitative measure of correlation between dynamic phenomena and is of great significance for analysis of emergence of turbulent states.

In natural sciences turbulence is interpreted as movement in continuous medium, in which one can observe formation of whirls as a result of velocity pulsation in separate local spheres. In aviation a zone of high turbulence designates an air-pocket. Turbulence arises in the flows of liquid, gas, liquid crystal, plasma, blood flow in a human's heart. This phenomenon is observed in quantum medium. Sometimes velocity of a turbulence flow is represented as an average value,

[5] Cotler Ph. Khaotika: upravlinnia ta marketynh v epokhu turbulentnosti / Ph. Cotler and J. A. Caslione [translation from English, ed. by T.V. Spivakovska, S.V. Spivakovskyia]. – Kyiv: Khimdzhest, Plaske. – 2009. – P. 14.

[6] Mandelbrot B. Fraktalnaia heometriia prirody / B. Mandelbrot. – M.: Institut kompiutornykh issledovanii, 2002. – 656 p.

which is formed on the basis of a pulsation component[7]. Turbulence state is often determined as chaotic. But such interpretation is not absolutely precise. Turbulence is revealed as a velocity space, i.e. movement of elements which earlier belonged to the same system with different velocity rates. These elements are moving not like particles in Brownian movement, but show space organization and form whirls.

At the early stages of turbulence studying main attention was paid to transition of energy from large-scale whirl-like structures to little-scale ones. Such transition of energy led to loss of structures' stability.

In the 1960s characteristics of the edge states and their role in turbulence weakening, as well as importance of liquid viscosity for turbulent processes came to the foreground. Over the recent years two hypothesis to explain turbulence in natural sciences have been used, namely chaotic self-oscillation and chaotic attractor. First explains appearance of turbulence by the system of reverse ties, which spread in the media of turbulence processes flow; under the second one, formation of self-reconstruction whirl-like structures is connected with presence of pluralities, which attract each other. Currently, these hypotheses are not considered promising. In natural sciences the problem of transition from a stable (laminar) movement to a turbulent one and back has not been decided yet[8].

R. Mantegna and H. Stanley compared emergence of turbulence in natural environment with formation of prices on financial assets. The first process is represented by wind variability in the atmosphere on the height of 6 m; the second one – dynamics of index S&P 500. The authors came to the conclusion that processes in two different spheres are very alike on the outside, but have various quantitative characteristics[9]. Both phenomena are described by the exponent law $\sigma(T) \sim (T)^{\upsilon}$, however for a change of a market index the value is $\upsilon = 0{,}53$, i.e. variables are not adjusted. For a wind speed $\upsilon = 0{,}33$, correspondingly these variables are not correlated. At the same time, both above-mentioned processes in different ways reveal a possibility to return to the initial state.

We assume, that juxtapositions conducted by R. Mantegna and H. Stanley are not correct. First of all, formation of a market index happens under influence of players who wish to forecast each other's actions and to counter-play. This process is information-fueled and that is why very volatile, but it does not fall into separate processes which flow with different velocity. One should not mix volatile processes with turbulent: the former are characterized by fluctuations in wide diapasons; the latter are described by movement of separate elements with different velocity. It concerns a wind speed as well. In its nature this process is volatile and not turbulent.

[7] Yevdochenko Ye.A. Turbulentnost hlobalnoi ekonomicheskoi sredy: teoreticheskiie aspekty i prakticheskoie proiavleniie / Ye.A. Yevdochenko [Electronic resource]. – Access mode: http://www.irbis.kneu.kiev.ua:8080/ bitstream/2010/5535/1/112-119.pdf

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[9] Mantegna R., Stanley H. Vvedeniia v ekonofiziku: Korreliatsiia I slozhnost v finansakh / Translation from English / R. Mantegna and H. Stanley. – M.: Publishing house "Librokom", 2009. – 118 p.

Only in some cases during the movement of air masses turbulence can be revealed, in particular whirling of leaves on the pavement under gusts of wind. Such jerky movement is characterized by emergence of velocity fields.

Analyzing turbulence scientists face a combination of two types of movement: rectilinear and rotary. Velocity of the movements is different. In hydrodynamics the velocity of whirls can achieve 0,5 – 0,7 form the flow velocity, what allows to state a hypothesis as to a special role of relative velocity in turbulent phenomena[10].

From a general perspective, endurance is treated as a balanced state of processes in the economic system. Speeds of the main economic processes flows are equal. Thus, relative velocity of a specific process or its dynamics in comparison with a general variable nature of the system is null. Taking this into consideration, dynamism of the economic system can be interpreted as a non-zero one as to the relative velocity of specific economic processes[11].

Stability is peculiar of a static state of the economic system. It is characterized by a comparative proportionality of a change of specific processes, and at the same time relative velocity of separate elements of the system is not revealed. But turbulence is described by such value, when a mode of whirl rotation emerges. Acceleration of movement of some elements is combined with slowing-up of other elements' relative velocity. The more elements of the system acquire relative speed, the more turbulent dynamics is, like irregular whirl movement. Analyzing turbulence one should pay great attention to a maximum speed of cooperation circulation within the system. Only being aware of a maximum speed of cooperation, one can determine relative speed of its separate elements. Maximum speed of cooperation circulation is a movement velocity of the system in general. Within the economic system cooperation between individual elements is ensured by marketing of goods and services. Namely, velocity of concluding agreements can be considered as a maximum speed of cooperation circulation within the system. As a rule, it does not coincide with the velocity of discharging debts.

In this regard V. Burlachkov offers the following equation:

$$Cd = kCp, \quad (1)$$

where:

Cd – velocity of concluding agreements (equals a maximum speed of cooperation circulation);

Cp – velocity if discharging debts and correspondingly concluding agreement;

k – coefficient.

When k = 1 speeds of concluding agreements and discharging debts are equal. Consequently their relative velocity equals null and by this ensures the main condition of the economic

[10] Burlachkov V. Turbulentnost ekonomicheskikh protsesov: teoreticheskiie aspekty / V. Burlachkov // Voprosy ekonomiky. – 2009. – № 11. – Pp. 92.

[11] Kulikova N.N. Kontseptualnyie polozheniia stratehicheskoho analiza v usloviiakh turbulentnosti ekonomicheskoho razvitiia / N.N. Kulikova // Sbornik nauchnykh trudov po materialam Mezhdunarodnoi nauchno-prakticheskoi konferentsii "Nauchnyie issledovaniia i ikh prakticheskoe primeneniie. Sovremennoie sostoianie i puti razvitiia", 2011. – Odessa: Publishing house "Chernomorie", 2011. – Pp. 62.

system stability. When k < 1 there is a threat of turbulence, due to disability to discharge debts relative speed of the most important process in the economic system is not null[12].

One should take into consideration that a maximum velocity of cooperation circulation is a maximum velocity of information transmission within the system. When its elements acquire relative speed, there arises a field of velocity of information transmission. Variability of maximum velocity of information transmission presupposes circularity of economic development. Velocity of concluding agreement is growing during the periods of middle-term economic improvement, as well as during elevating phases of Kondratiev long waves of the economic market condition. Decreasing of velocity of concluding agreements equals the fall of effective demand.

Hedging operations form a special problem. These agreements can be concluded, but later under realization of systematic risk they can remain unsolved. That is why they can be considered fulfilled only after expiration of the corresponding agreements.

Relative velocity of a specific economic process can be changed for two reasons: changes of expandable equipment in the economic system or velocity of a specific progress. These reasons also stipulate economic turbulence as a manifestation of continuity of movement at relative velocity. Thus, stability of the economic system characterizes its state under null relative velocity of elements, which are included into it. Chaos is a state of the system under null velocity of cooperation circulation.

To understand turbulence and its mathematical interpretation it is necessary to apply analysis of relative velocity of specific elements of the system, as well as maximum velocity of cooperation circulation. In relativized physics velocity of moving objects correlate with the velocity of light as a maximum speed of cooperation circulation in the physical medium.

Extremely outstanding Lorentz transformation gives a possibility to deal with one and the same event in different systems of axes, i.e. different axes of reference which move relative to each other[13]. That is why in this case one uses relative velocity, as well as a maximum speed of light circulation. To transit from the system **X** to moving system **X'** the following equations of the Lorentz transformation are applied:

$$x = \gamma (x' + \upsilon t'); \; t = \gamma (t' + \upsilon x'/c2); \; y = y'; \; z = z', \; (2)$$

where:

$1\sqrt{1} - \upsilon 2/c2$ – Lorentz factor;

x, y, z – coordinates of the system **X**;

x', y', z' – coordinates of the system X';

υ – velocity of the system **X'** in relation to **X**;

c – light velocity.

[12] Burlachkov V. Turbulentnost ekonomicheskikh protsesov: teoreticheskiie aspekty / V. Burlachkov // Voprosy ekonomiky. – 2009. – № 11. – Pp. 93.

[13] Olsevych Yu. Ya. Sovremennyi krizis "meinstrima" v otsenkakh eho predstavitieliei (predvaritelnyi analiz). – M.: Institu ekonomiki RAN, 2013. – P. 37.

At first the Lorentz transformations were applied only to the systems, which move rectilinear and in parallel to each other, but when characteristics of non-commutability of these transformations were revealed, they became to be used to analyze systems of a wider class. Currently, the Lorentz transformations are used not only in relative physics, but also in other spheres of natural sciences[14]. However, allowability of their usage under analysis of the systems with non-relative velocity, i.e. considerably less than the velocity of light, remains at the level of a scientific hypothesis. We suppose that the Lorentz transformations are quite suitable for studying specific systems in the course of their transformation to the movement with various speed regimes. In this case velocity of the system is revealed in point **A** in relation to velocity of this system in point **B**.

L. Sabinin and P. Mikheev state that supplement of relative speeds is neither non-commutative nor associative[15]. Non-commutative process is asymmetric. And quite the contrary – commutative nature represents symmetry. Non-commutative nature represents a significant specificity of the process – succession and inequality of concrete stages. Non-associative nature reveals inconvertibility of a process. Crucial significance is inherent to the question of a possibility to apply dynamics pace (dimensionless indices) instead of velocity index (which has measurability – km/s) in the Lorentz transformation. Pace as well as velocity is a relative index. We suppose, its usage even simplifies calculations, excluding time variable.

The Lorentz transformations mathematically describe not only spatial movement in a straight line, but also rotation. One can imagine two consequent transformations, which transmit the system from the state $\mathbf{S}_0$ into the state $\mathbf{S}_1$ and $\mathbf{S}_2$. At the same time the velocity of the system changes. But two consequent transformations $\mathbf{B}_1$ and $\mathbf{B}_2$ are not equal with the third transformation $\mathbf{B}_3$ due to non-commutative characteristics. Third transformation includes rotation through an angle ω. As Ch. Misner, K. Thorne and J. Wheeler stated velocity of such rotation is determined by acceleration of the system movement[16]. This characteristic of relative velocity change can be described as follows:

$$\mathbf{B}(\upsilon 1)\mathbf{B}(\upsilon 2) = \mathbf{C}(\omega), \mathbf{B}(\upsilon 1 + \upsilon 2), \quad (3)$$

where:

$\upsilon 1, \upsilon 2$ – vectors of relative velocity;

B – operator of a straight-line movement of the system;

C – operator of its rotation; (ω) – angle of rotation.

Equation (3) shows, that a change of relative velocity includes two operators: the first one ensures a straight-line movement of the system, the second one – its rotation through the angle ω. Under a certain correlation of relative velocity elements of the system can do not just a turn,

[14] Baskal S., Kim Y. Rotations Associated with Lorentz Boosts / S. Baskal, Y. Kim // Journal of Physics A: Mathematical and General. – 2005. – Vol. 38. – № 29 [Електронний ресурс]. – Режим доступу: www. physics.metu.edu.tr/~baskal/jpa-bk05.pdf.

[15] Sabinin L. V., Mikheev P. O. O zakone slozheniia skorostei v spetsialnoi teorii otnositelnosti / L. V. Sabinin, P. O. Mikheev // Ispekhi matematicheskikh nauk. – 1993. – Vol. 48. – Issue 5 (293). – Pp. 183-184.

[16] Misner Ch., Thorne K., Wheeler J. Hravitatsiia / Ch. Misner, K. Thorne and J. Wheeler. Vol. 3. – M.: Mir, 1977. – P. 405.

but a full U-turn. It means that a change of relative velocity can lead to a whirl formation. It is clear that in this case we discuss only peculiarities of mathematical description of a specific phenomenon – change of relative speed of the systems' elements. Quantitative analysis allows existence of a rotation operator of mathematical changes of relative velocity[17]. But it does not mean that such operator must obligatory be present in physical and especially in economic processes. In this case it is necessary to conduct qualitative analysis of specific phenomena, which will prove or refute a possibility to form a whirl-like movement within the systems under a change of relative velocity of movement of the system's elements.

Each specific element of the system under the increase of relative velocity falls within the scope of rotation. At that, the main factor of asymmetry arising is a leap of the system's velocity, which appears as a result of rapid acceleration. We believe that such interpretation can be applied to economic processes. As a result of a change of a velocity regime, this is presupposed by relative velocity of separate elements of the economic system, in which a whirl-like movement is formed, as a zone of instability with a multidirectional dynamics of market indices. A whirl-like effect in the economic system is revealed as a result of a rapid change of movement velocity of its elements as to a maximum speed of cooperation circulation. In particular, velocity leaps break a balanced nature of a system. But when the velocity of the system's elements is close to a maximum velocity of cooperation circulation such leaps are not significant, and the rotation effect appears to be a minimal one.

"Bubbles" at the stock and mortgage markets of the USA became the results of relative velocity manifestations of the interrelated processes or differences in their dynamics. Correspondingly, cancellation of a turbulent state is connected with restoration of certain correspondence between velocity types within the system

In economy turbulence can appear, if a pace of discharging debts is lagging behind a pace of concluding agreements, i.e. formation of obligations. It is proved by dynamics of total debts of the national economics of well-developed countries, in particular the USA, over the periods, which precede the biggest financial disruptions, namely the 1929 and 2008 crises. The degree of national economics' debts, when from 30% up to 50% of agreements in the consumers sector are concluded in credit can be treated as critical. In this situation a whirl-like effect arises. A turbulent state of economy is presupposed by breaches in paces of progress of such interrelated processes as demand and supply, production and consumption, saving and investment.

Therefore, knowledge of turbulence laws allows determining not a single trajectory of the state's development, but a whole vector field of the most possible (stable) wave-shaped changes. One should bear in mind an unchangeable law of chaos: projecting something, we get something quite different, which is on the edge of projected (i.e. something which just resembles the initial plans).

[17] Sabinin L. V., Mikheev P. O. O zakone slozheniia skorostei v spetsialnoi teorii otnositelnosti / L. V. Sabinin, P. O. Mikheev // Ispekhi matematicheskikh nauk. – 1993. – Vol. 48. – Issue 5 (293). – Pp. 183-184.

The conducted analysis gives us an opportunity to make the following conclusions. Firstly, turbulence is a characteristic feature of various processes, including economic ones, thus this is a feature of economic dynamics. Application of a procedural approach in macroeconomics presupposes usage of such notions as turbulence and relative velocity of processes.

Secondly, turbulence appears as a manifestation of relative velocity of specific processes. In this case economic system can lose its stability. Consequently, balance is a state of economic system under null or minimal relative velocity of its elements. Turbulence as a mechanism of instability arises not under null relative velocity of the system's elements. In this sense turbulence is a characteristic of constituent elements of any process to obtain relative velocity.

Thirdly, due to the analysis of economic processes we may conclude that the reason of turbulence is in representation of a relative velocity of separate elements of the system while preserving a maximum velocity of cooperation circulation within it. Such approach gives a possibility to apply the Lorentz transformations for a mathematical description of turbulence of economic phenomena.

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